Turning Number into Knowledge

BEGINNER'S MIND

Beginners to any art don't know what is important and what is irrelevant, so they try to absorb every detail. Experienced martial artists use their experience as a filter to separate the essential from the irrelevant. When that filter mistakenly screens out something essential, then even seasoned masters can err.

INFORMATION, INTENTION, AND ACTION

Your decisions are a function both of your past experiences, evaluated after the fact, and your current needs and desires. Your past experience enjoying particular recordings, for example, combined with your current goals of hearing music, will help you decide whether to choose one compact disc over another.

As Edward Tufte says, bad table and graph design reflects sloppy thinking.

PEER REVIEW AND SCIENTIFIC DISCOVERY

Most people (especially nonscientists) don't recognize the large role that intuition and instinct play in scientific discovery, particularly in the process of developing hypotheses. A scientist's desires for recognition and status, enthusiasm for solving a problem, and attitudes towards authority are all motivations rooted in human needs and emotions.

The formal process of peer review is most often conducted for articles submitted to scholarly ("peer-reviewed") journals or for research proposals submitted to funding agencies (such as the National Science Foundation). In journal reviews, the author submits the article to the editor, who then distributes the article to between one and four reviewers. The reviews are sometimes "blind" so that the reviewers don't know the names of the authors and their affiliations (it is however often possible for knowledgeable reviewers to infer the identities of the authors from a paper's citations and the authors' approach in presenting the results). More often, the authors' names are known to the reviewer. Only rarely is the reviewer's name revealed to the authors when comments are delivered. Both the number of reviewers and whether the reviews are blind are at the discretion of the journal editor.

The purpose of peer review is to judge whether the work is based on principles and judgments that represent the current scientific consensus. When such a consensus exists in a particular field, it reflects the paradigm accepted by scientists in that field and gives practitioners a standard set of tools with which to evaluate new ideas (see Kuhn's Structure of Scientific Revolutions for more details). When a paradigm is challenged by anomalous observations and experiments, a crisis ensues. The crisis continues until a new paradigm emerges that encompasses the anomalous results. During periods of crisis (or in non-scientific fields) peer review is generally less reliable because the foundations upon which the reviewers judge research results in the field are being questioned in fundamental ways.

Peer review does not guarantee accuracy. In fact, papers containing major scientific blunders have been published in peer-reviewed journals. However, the formal peer review process makes it more likely that a paper will avoid major flaws.

How can you tell if a scientific study has been peer reviewed? Table 4.1 lists some important peer-reviewed journals for key scientific fields. If the study is published in one of these journals, it's passed the first hurdle of basic scientific credibility. For a long (but still probably incomplete) list of peer-reviewed journals, check out <http://adswww.harvard.edu/abs_doc/refereed.html>. For a ranking of the importance of different journals in virtually all scientific fields, see the Science Citation Index, put out annually by the Institute for Scientific Information or ISI <http://www.isinet.com>.

There are two kinds of reasoning accepted in scientific research. The first, based on deductive logic, relies on assumptions and general principles to derive implications and predictions of specific events. If I leave my bicycle outside and it rains, I deduce from my experience and the laws of chemistry that parts of the bicycle will rust. Deductive inferences rely on a set of initial assumptions ("axioms"), which are analyzed using rules of logic. If the initial assumptions are correct, the rules of logic are followed, and no logical contradictions arise in the analysis, then the conclusions must be correct.Table4.1here The second kind of reasoning–inductive logic, on which many inferences in science and other forms of human endeavors are based–relies on compilations of specific instances to infer general laws from the specifics (see Hughes, Critical Thinking). If I leave my bicycle unlocked outside for a hundred days and it is never stolen, I could use inductive reasoning to infer that it will not be stolen tomorrow, but I cannot be sure. I can only say that it is unlikely to be stolen, based on my extrapolation

of past experience. Inductive reasoning is less certain than deductive logic (in rare instances it can be as certain, but never more so).

The physicist Alan Sokal points out that science is predicated on two key attitudes:
• being willing to accept what you find; and
• being willing to discover that you are wrong.

EXPLORE YOUR IDEOLOGY

Anyone who states that ideology has no effect on decisions is lying, deluded, or woefully ill-informed. Everyone has an ideology whether explicit or not. Ideology provides a simplified model of the world that reflects our values, biases, and experiences. It helps people make decisions in the face of imperfect knowledge.

Anton Flew's Dictionary of Philosophy defines ideology as "any system of ideas and norms directing political and social action," indicating the key role it plays in mediating between ideas and choices. Ideologies are often explicitly political (libertarian, conservative, liberal) but may also relate to preferences about material things.

Computer users each see themselves in ways that reflect their ideologies. Apple Macintosh users, for example, often see themselves as going against the conventional wisdom–resisting the crowd mentality by choosing a computer they regard as technically superior (in the late 1990s, Apple fed that perception in its advertising, associating, for example, Albert Einstein's unconventional brilliance with its products). Microsoft Windows users, on the other hand, stereotypically see themselves as realists who are adopting the standard because they perceive its complete dominance to be inevitable, because they believe it is cheaper, because they value the greater availability of software for Windows, or because they are forced to use it at work.

Ideology is one connection between the world of ideas and the world of choices.

It is essential to think through your ideology so that it will be consistent. You can check its external consistency by examining how its assumptions and conclusions stack up against facts you know for sure. Sometimes there is no way to check external consistency, and we say in this case that the assumptions behind the ideology are not falsifiable, testable, or provable. We can always test internal consistency, however. If there are internal inconsistencies, we know there's something wrong.
To help think about your ideology, ask yourself these questions:
• Where do you get your information?
• Whom do you trust? Why do you trust them?
• With whose opinions do you normally agree? Do you agree with all their opinions? Why do you agree? Do you believe in their values or do you trust their judgment?
• To whom do you give the benefit of the doubt? Why?
• Are there events that outrage you? Why do they make you mad?
• What motivates you to work hard? From where did those motivations come?
• Could one part of your ideology lead you to take actions that would be inconsistent with another part of your ideology?

Ideology is the filter through which you view the world. By exploring your own body of beliefs, you can more reliably make choices that are consistent with your values, and you will also be better prepared to use numbers responsibly and effectively in your analyses, writing, and presentations.

GET ORGANIZED

Raw intelligence is the ability to think quickly and accurately; useful intelligence is raw intelligence as enhanced by hard work, common sense, instinct, experience, discipline, and organization. A person of moderate raw intelligence who possesses high useful intelligence will virtually always be more productive than a brilliant person who lacks the personality traits needed to make that brilliance useful in the world.

Julie Morgenstern, in her book Organizing from the Inside Out, gives sound and practical advice for getting organized. By following her systematic approach for assessing your goals and analyzing your current state of disorder, you can begin to get control of the chaos. After you've used Morgenstern's tricks and tips for assessing and addressing the situation, you can take the following additional steps to achieve effective personal organization:

• Control information flows: Decide which information streams are relevant and which are detrimental to your professional effectiveness. Cancel magazine and newspaper subscriptions except those you use regularly. Limit your use of the World Wide Web to get news updates–with few exceptions, checking more than once a day is a waste of time and effort. Set aside specific times to answer mail and email (there's usually no need to respond to emails as they arrive). Recycle junk mail without opening it
.
• Buy a paper or electronic organizer: Track to-do tasks, appointments, addresses, phone numbers, and notes in an orderly way. Get rid of the myriad slips of paper that confuse and confound. A trick I recently discovered to keep track more effectively of to-do tasks is to create a blank page with different types of actions (like "call," "do," "email," "fax," "investigate," "find," "visit") and to write down your tasks under the appropriate category (see Figure 6.1). This approach immediately creates a task-oriented hierarchy that helps you prioritize. I keep separate pages like this for work and home to-do tasks. If things are really busy, you can even keep separate pages for different projects.

• Clean your office: Throw out extraneous stuff and store rarely used books. Make frequently used materials easily accessible. Keep only current work on your desk and put other materials in drawers and filing cabinets. Identify those items that are important to you and make them accessible. Morgenstern says "keep what you use and what you love. Toss the rest." Spend fifteen minutes at the end of each day to tidy up your office, so you can start fresh in the morning.

• Develop a filing system: Filing is for retrieval, not storage. Create a filing system that helps you (or others) retrieve stored information in a timely fashion. If you can't find an article or electronic file, it's worse than useless because you waste time looking for it. Be selective about the items you file.

• Take time to reflect: Make sure you give yourself at least a half-hour per day of solid thinking time, with no interruptions. Unplug the phone and turn off the radio.

• Prioritize tasks and focus on the essential: Too often, our days are consumed by "urgent tasks that are not important." For at least part of the day, focus on the "important tasks that are not urgent."

• Document, document, document: Documentation creates a trail for you and others to follow after the fact. It is essential to any intellectual work, but is often neglected. By making it a priority, you ensure that your intellectual contribution will remain important and useful for years to come.

BUILD A TOOLBOX

LANGUAGE

Each field has its own language. You must at least develop working familiarity with basic concepts in a given field before attempting to decipher a problem. If you are delving into a field for the first time, obtain a textbook and begin your reading there. Textbooks conveniently summarize the core information in a given field and usually provide a nice glossary and lists of further references. Another good place to begin is the list of frequently asked questions (FAQs) on a particular topic that is available on the Internet for virtually any issue you can name <http://www.faqs.org>. Talk to people you trust who know something about the topic because they can often point you to the best reference sources
and save you time.

CALCULATIONS

An important part of any analyst's toolbox is the ability to create simple back of-the-envelope calculations at a moment's notice, using approximations and memorized data. Such calculations are a quick way to check the quantitative assertions of others and are invaluable in both business and science.

Darrell Huff's book, The Complete How to Figure It, is a beautiful compilation of hundreds of ways to calculate numbers important to daily life. Another nice source of math techniques is a book written by Clifford Swartz called Used Math. It is more advanced than Huff's book, and summarizes the basics of calculus and other essential mathematical tools, mainly for students of science. If you find yourself needing to refresh your knowledge of more advanced math, this book is a great place to start. For an accessible and entertaining book about statistics, try Larry Gonick and Woollcott Smith's The Cartoon Guide to Statistics. Don't let its title fool you. It's a solid introduction to statistical concepts and methods.

PUT FACTS AT YOUR FINGERTIPS

The single most important document for a U.S.-based researcher in virtually any quantitative field is the Statistical Abstract of the U.S. It is available every year from the U.S. Superintendent of Documents and other sources for around $40.

A companion to the Statistical Abstract is a good almanac. Although some data in these two sources overlap, the almanac contains many useful items that The Statistical Abstract doesn't have, such as zip codes, postal rates, tax rates, historical events, sociopolitical facts about states and countries, and other information that you didn't know you really needed (but you really do). There are many almanacs; the one I have is The World Almanac and Book of Facts <http://www.worldalmanac.com>. Time Magazine, The New York Times, and The Wall Street Journal also publish almanacs, some of which are more specialized than others. An almanac of some kind will be available in any bookstore or library, or you can access the Information Please Almanac on the web at <http://www.infoplease.com/>.

Many newspapers and magazines offer searchable archives of past issues on the web or on CD-ROM. Using such archives makes initial research on new topics relatively easy. The New York Times, for example, allows web readers to search the past 150+ years of archived articles and to see the results of the search in summary form <http://www.nytimes.com>. Many public libraries offer access to similar CD-ROMS and on-line databases, so check your local library before buying.

Another excellent source of data is a book by Mary Blocksma called Reading the Numbers. This book summarizes the meaning of numbers we encounter in everyday life, like the codes found on the side of tires or the conventions used in describing fluorescent light bulbs. It is unfortunately out of print but can be obtained at used bookstores, <http://www.alibris.com>, and some libraries. A similar book that is more readily available is Andrea Sutcliffe's Numbers: How Many, How Long, How Far, How Much. The variety of data contained in this book is truly astounding. In one section there are estimates of safe food storage times in the refrigerator and freezer, and in another there is a list of the number of different types of instruments in a typical symphony orchestra. The major sections include money, food and nutrition, health, travel, daily life, transportation, time, weather, people and places, the universe, conversion tables, and everyday math. The book contains more than 600 pages of data, and it's well worth having on your shelf.

Worldwatch, in Vital Signs 2007–2008, presents essential information related to resource consumption and environmental effects around the world. These data include pollutant emissions, freshwater resources, land use, population and health, food and agriculture, wildlife and habitat, energy, atmosphere and climate, and policies and institutions. The data in Vital Signs are also available electronically from the Worldwatch Institute <http://www.worldwatch.org>.

WEB/INTERNET DATA

More data appear on the Internet every day. It is an impossible task to report the latest developments in a book like this one (things change too quickly), but there are a few key sites of which you should be aware. All URLs and changes to them can be found at <http://www.numbersintoknowledge.com>.

- The Library of Congress site <www.loc.gov> is an invaluable source. You can search the library's databases with little effort. Many local libraries have also placed their catalogs on the Internet, which can save you a trip next time you want to do research.
- The U.S. Bureau of the Census site <http://www.census.gov> is beautifully designed and is a treasure trove of social, demographic, and economic data. You can search by key word, by place, by clicking on maps, and in many other ways. Most of the data on this site are free or available at nominal cost. This site also houses the on-line version of the Statistical Abstract of the U.S. <http://www.census.gov/compendia/statab/>.
- The National Technical Information Service (NTIS) is still, as of this writing, the official source of many U.S. government reports. NTIS sells almost three million titles, and you can search on its nicely designed web site <http://www.ntis.gov> to find the one you want.
- The U.S. Department of Energy's Energy Information Administration site <http://www.eia.doe.gov> is the right place to find energy and some environmental data for the U.S. The site also has limited information on certain international topics, such as nuclear power or energy use in other countries. Most of the data on this site are free or available at nominal cost.
- The U.S. Environmental Protection Agency's site <http://www.epa.gov> contains huge quantities of environmental data, as well as access to the EPA's reports.

• The Fed Stats site is a treasure trove for U.S. economic and other data <http://www.fedstats.gov>. It allows easy access via the World Wide Web to data from more than 50 federal agencies.
• The Economagic web site, which has both U.S. and international economic data, is located at <http://www.economagic.com>. This site claims to offer access to 200,000 data files (many of them for free), with special services for subscribers (fees for subscribers range from small to moderate depending on the level of service).
• The National Center for Health Statistics site <http://www.cdc.gov/nchs> contains data and reports on U.S. health that can be downloaded for free.
• The U.S. Geological Survey produces a superb on-line atlas for the United States, which can be found at <http://www.nationalatlas.gov>. This site allows the user to map standard political boundaries, identify the locations of airports and dams, and overlay the routes of roads and railroads. It also contains maps of Superfund sites, air pollution emissions, mining operations, industrial facilities, and selected data from the U.S. Census.
• Frequently Asked Questions (FAQs) exist on the Internet for almost any topic <http://www.faqs.org>. Because these FAQs are compiled by experts in each field, they are a great place to begin your inquiries. Use Internet search engines to find the FAQs that will help you most.
• There are hundreds of newsgroups on everything from Star Trek to statistical analysis. By posting an email to the relevant newsgroup, you can often get answers to questions from people all over the globe in a matter of hours or days. You can generally access these newsgroups using your web browser (consult your Internet service provider for details, or go to <http://groups.google.com>).

CONTEXT

Sometimes in presenting the results of analysis, you'll want to know the intellectual history behind a certain concept. For example, if you are giving a talk about energy policy to a general audience, you might want to open with a brief summary of how the concept of energy was developed and how our modern conception differs from that common in the 1800s. In this circumstance, two essential works are The Encyclopedia of Philosophy and The Oxford English Dictionary. The former is helpful in tracing the genesis of a particular concept through the ages while the latter tracks the origins of particular words. Each of these sources can be useful in writing a speech or a paper and are both found in most libraries.

An alternative to the conventional Encyclopedia of Philosophy is The Stanford Encyclopedia of Philosophy, which is a web-based encyclopedia of comparable scope to the hard-copy version, on line at <http://plato.stanford.edu>. It is constantly being updated and evaluated by its editorial board (they call it a dynamic encyclopedia). The creators of this new tool felt that the old way of creating an encyclopedia was too slow to capture the rapid developments in philosophical thinking (particularly developments related to scientific concepts).

A good book of quotations is essential to liven up your writing and presentations, and a standard dictionary and thesaurus will make your writing more precise. These are available in myriad incarnations in any bookstore. You can also search Roget's thesaurus at <http://humanities.uchicago.edu/forms_unrest/ROGET.html> or the Merriam Webster thesaurus at <http://www.m-w.com/thesaurus.htm>.

For many academic topics, excellent summaries of the current state of research are contained in Annual Reviews. These reviews are published for 27 different fields, including political science, public health, the environment, and the physical and biological sciences. They are often the best place to start when you're trying to learn about a new field.

CONVERSION FACTORS

For physical constants and conversions, there's nothing better than The Handbook of Chemistry and Physics. It comes out every year, but because physical laws and constants rarely change even an old version of this work is handy.

VALUE YOUR TIME

The most articulate statement of this principle is found in Your Money or Your Life. In this book, Joe Dominguez and Vicki Robin describe a set of simple techniques to help people internalize this equation and make it part of their daily decision making. They encourage people to evaluate their spending by calculating how many hours of labor ("life energy") will need to be spent for each purchase. The value of money becomes more real after you ask yourself two key questions:
• "Did I receive fulfillment, satisfaction, and value [from this purchase] in proportion to life energy spent?"

• “Is the expenditure of life energy on this purchase in alignment with my values and stated life purpose?”

One hundred dollars has an abstract quality. It is made more real when comparing various purchases that can be made for that amount. It becomes most real when put in terms of the four or eight or twenty hours of labor needed to earn the money to buy this new toy you want.

Be selective about the endeavors on which you spend time. Prioritize. Choose jobs with the greatest likelihood for success and the highest potential payoff. Working at a dead-end job can sap time and energy from a more valuable use of your time.

Think carefully about time spent with others: Does it add to your life? Does it make you happy? If not, then do something about it. Don’t let anyone steal your life!

You must protect your most productive time from interruptions. Each of us works best at particular times of day.

If you are feeling unproductive, do something that takes little mental energy or effort but will yield dividends later (like sorting your files, reading mail, or answering phone calls). Even “down time” can be useful if you match the task to your mental energy level.

THE POWER OF CRITICAL THINKING

When we express an inference in words, we do so by means of statements. A statement is a sentence (i.e. a set of words) that is used to make a claim that is capable of being true or false.... An argument is a set of statements that claims that one or more of those statements, called the premises, support another of them, called the conclusion. Thus, every argument claims that its premises support its conclusion.

A logically strong argument, according to Hughes, is one “whose premises, if true, support its conclusion.” A sound argument is “a logically strong argument whose premises are true.” Critical thinking is the way to identify and create sound arguments, which is the main goal of all analysts.

Hughes describes the key steps a critical thinker uses to assess arguments and decide whether they are sound.31 I summarize his steps below:

• “Identify the main conclusion”: Rephrase the main conclusion in your own words, to be sure you understand it. Think about the context in which the argument is being made. Finally, if the argument is not stated clearly, interpret the argument in the way that is most charitable to your opponent’s views (Hughes calls this “the principle of charity”).

• “Identify the premises”: Rephrase the premises in your own words. List the unstated premises and assumptions. Discard distracting and irrelevant examples that are not really premises. Don’t forget that context is important, and that the principle of charity should guide your interpretations at this stage as well.

• Identify the logical structure of the argument and determine how the premises support the conclusion: Determine whether one premise depends on another one, or, alternatively, if premises are independent of each other. Determine whether the argument contains sub-arguments that support the ultimate conclusion. Hughes presents a way of describing the structure of arguments, known as a tree diagram, that can help with this step.

• Ask whether you’d be justified in accepting the premises: In most cases, a strict proof of the premises is impossible, so we must be satisfied with the less stringent standard of “acceptability.” Hughes suggests two criteria for evaluating acceptability:
— If the statement is common knowledge, we should regard it as acceptable, unless the context requires a higher standard of proof.
— If the statement is not common knowledge, we should ask for, or be prepared to offer, the evidence upon which it is based, and accept it only if the evidence meets the appropriate standard, for example, personal experience, appeal to a recognized authority, or strict proof. Hughes also points out that “common knowledge” is often wrong, so use care when relying on any measure of acceptability less than a true proof. Key questions to ask when determining acceptability include: Are the premises common knowledge? What is the context of the argument? Who is making the argument? Are they experts? Do they have a vested interest in the outcome? Are

the premises backed up by credible research published in peer-reviewed journals? Are the premises based on consistent comparisons?

• Ask whether the premises are relevant: Many arguments are peppered with premises that are irrelevant to the conclusion but appear to support it. Usually the previous steps will make it obvious which premises don't apply, but it's worth asking the question again at this stage just to be sure.

• Ask whether the premises "adequately" support the conclusions: Certain statements lend some support to the conclusion but are not sufficiently compelling to make the argument adequate (appeals to authority often fall into this trap). Inadequacy is a key weak point of many arguments. This step is mainly an exercise in common sense and in figuring out whether a particular argument accounts for all of the many possibilities.

• Look for missing arguments: Omitting a valid comparison is one commonly used way to make an argument seem stronger, so try to find these omissions in other people's arguments. People often look for the best-case comparisons to support their own position and ignore comparisons that might weaken their case.

• Finally, "Look for counter arguments": Try to find a sound argument that leads to a conclusion contradictory to the one reached by the argument being evaluated. If you find such a counter argument, you know that something's wrong, because two sound arguments cannot contradict each other (unless one is not truly sound).

Four categories of things affect decisions in the world:

• Some things can be measured directly and with confidence before decisions have to be made. The amount of money in your bank account at the time of your last statement falls into this category.

• Some (perhaps most) things are not directly measurable but can be estimated accurately enough in time to influence decisions. You cannot know exactly how much money you will have in your bank account in a month, but you can estimate it in a crude way by making assumptions about your expenditures, based on an extrapolation of past spending trends and planned expenses.

• Some things cannot be measured, estimated, or predicted accurately in time to influence decisions. Some reasonable estimate might be possible for such factors, but time is often limited. For example, time constraints may prevent you from doing a complete analysis of your assets before rushing to put a bid down on a house.

• Some things cannot in principle be measured, estimated, or predicted under any circumstances. Sometimes there are physical reasons for this inability (e.g., the Heisenberg uncertainty principle limits the accuracy of measurements of the velocity and position of subatomic particles) and at other times we cannot measure or predict because things that really matter to people's lives (such as loyalty, love, honesty, and integrity) are simply not quantifiable in any meaningful way. It is not possible to estimate the true value of a warm summer's day or a species saved from extinction except in terms that have nothing at all to do with numbers.

Believers in an unbreakable link between energy use and GDP assigned the immutability of a physical law to this historical relationship but found their belief shattered by events. From 1973 to 1986, U.S. primary energy consumption stayed flat, but GDP rose 35% in real (inflation-adjusted) terms. These believers had forgotten that people and institutions can adapt to new realities, and historically derived relationships (like the apparent link between energy use and GDP that held up for more than two decades in the post-World-War-II period) can become invalid when events (like the 1973 oil embargo) overtake them.

Hughes, in his book Critical Thinking, proposes five criteria to use when assessing the assertions of an ostensible authority figure. I summarize them below:
• "The authority must be identified": Appeals to anonymous authorities are immediately suspect. You can't assess the strength of an appeal to authority without knowing who the authority is.
• "The authority must be generally recognized by the experts in the field": At a minimum, the authority must possess an academic degree, a professional license, or an institutional position that indicates acceptance by the relevant expert community.
• "The particular matter in support of which an authority is cited must lie within his or her field of expertise": The authority must be a real expert on the topic at hand, but it is common for experts in one field to express opinions about another field, and be taken seriously whether their opinions are well founded or not (the Robert Young example described above is a case in point).

• “The field must be one in which there is genuine knowledge”: Hughes defines genuine knowledge as “a systematically ordered body of facts and principles that are objective in nature.” Beware of appeals to authority in fields that don’t fall under this definition.
• “There should be a consensus among the experts in the field regarding the particular matter in support of which the authority is cited”: Even in physics, there are issues that remain a subject of controversy. Appeals to authority are only relevant on topics that are not controversial.

DON’T BELIEVE EVERYTHING YOU READ

WHAT SCIENTISTS SAY, AND WHAT THEY MEAN: A FACETIOUS GUIDE FOR THE PERPLEXED

PHRASE	TRANSLATION
It has long been known	I haven't bothered to look up the reference
It is believed	I think
It is generally believed	A couple of other guys think so, too
It is not unreasonable to assume	If you believe this, you'll believe anything
Of great theoretical importance	I find it kind of interesting
Of great practical importance	I can get some mileage out of it
Typical results are shown	The best results are shown
3 samples were chosen for further study	The others didn't make sense, so we ignored them
The 4-hour sample was not studied	I dropped it on the floor
The 4-hour determination may not be significant	I dropped it on the floor, but scooped most of it up
The significance of these results is unclear	Look at the pretty artifact
It has not been possible to provide definitive answers	The experiment was negative, but at least I can publish the data somewhere
Correct within an order of magnitude	Wrong
It might be argued that	I have such a good answer for that objection that I shall now raise it
Much additional work will be required	This paper is not very good, but neither are all the others in this miserable field
These investigations proved highly rewarding	My grant is going to be renewed!
I thank X for assistance with the experiments and Y for useful discussions on the interpretation of the data	X did the experiment and Y explained it to me

What should you do to protect yourself and others from such shenanigans?
• First, go back to the questions. Read the questionnaire. Find out who asked the survey questions and how they settled on the survey sample.Also determine when the questions were asked, because that can sometimes affect people’s responses.
• Be a detective and determine the potential motives of the surveying organization. Identify the funding sources for the research.
• Dig into the numbers, and compare results to other numbers you know to be true. Are results consistent with other sources? Can you find internal inconsistencies that cast doubt on the results? Answers to these latter two questions made it obvious that the SPA results were nonsense.
• Finally, don’t email information to dozens of people unless you are confident it is true. I’ve received dozens of email warnings about computer viruses that will erase my hard drive or have some other terrible effect. I know

most of these are bogus because they usually don't mention which kinds of computers they affect, and all genuine warnings are very clear about the software that is affected by a given virus. Viruses (with a few exceptions) afflict Macs, PCs, or UNIX machines, but one type of machine can't generally "catch" the virus from another type. Before forwarding ANY email about computer viruses, check out the latest information at the Symantec Anti-Virus Research Center, <http://www.symantec.com/avcenter/index.html>.

To truly understand the meaning of a survey, it is essential to go back to the original survey questions. Never base critical decisions on someone else's summary of survey results unless you have implicit trust in that person's judgment and understanding of the situation. It is also crucial to understand how the sample of respondents was selected (self-selected samples are the bane of a good analyst's existence). The sample must be truly representative of the population or else the results are suspect.

READING TABLES AND GRAPHS

When reading a new report, I go straight for the tables and graphs. I do this for two reasons:
• I want to determine whether I find the author credible, and
• I like to understand the bottom-line results.

These two goals are quickly served by rummaging through tables and graphs for half an hour. If the tables and graphs are good enough, I read the paper to follow the author's reasoning more closely. If the tables and graphs are poorly designed or confusing, I lose respect for the author. It is essential that tables and graphs summarizing analysis results be clear, accurate, and well documented. If they aren't, including them is worse than useless because they hurt your argument and your credibility. First check for internal consistency. I always begin at the bottom-line table and work backwards. I examine the column and row headings to be sure I understand what each one represents (I read the footnotes if I have questions). I then assess whether the components of the total add up to the total. This procedure shows me whether the calculations are accurate, and it helps me become familiar with the different parts of the analysis.

Next, look over the numbers in the table and identify those that are abnormally small or large. Typographical errors are quite common in tables (particularly in tables that summarize results from other, more detailed tables), and a quick scan can help you find them. For example, if you're reading a table summarizing hours worked per week by different team members on a project, an entry from one person that's ten times larger than the entries for others should catch your attention and prompt you to investigate further. The number may not be wrong, but checking it will increase your confidence in the analysis and help you understand it more fully.

DISTINGUISH FACTS FROM VALUES

This portrayal cannot be correct—if an analyst makes a choice, he has also made a value judgment. For example, Bernard L. Cohen portrays his support for a revival of nuclear power as the result solely of scientific analysis when in fact it is a public policy judgment that is based both on his values and his scientific understanding.

Robert Reich's public policy students often forgot that values (and hence politics) are always intertwined with public policy choices:

> "Some of my students used to regard public policy-making as a matter of finding the "right" answer to a public problem. Politics was a set of obstacles which had to be circumvented so the "right" answer could be implemented. Policy was clean–it could be done on a computer. Politics was dirty–unpredictable, passionate, sometimes mean spirited or corrupt. Policy was good; politics, a necessary evil."

I define facts as assertions about the physical world that can be verified through experiment, direct measurement, or observation. Events can also be facts although the interpretation of the meaning of those events is usually strongly colored by ideology and attitudes. Values, on the other hand, are explicitly subjective and are an expression of the ideas and feelings that are most important to us. As the philosopher Ken Wilber points out, the only way to truly understand values (or other beliefs) in all their complexity is to engage in a dialogue with the person who holds them.

Understanding the relationship between facts and values can aid decisionmaking. If people agree about both the facts and the values related to a particular decision, reaching an acceptable solution becomes merely an issue of computation. A situation in which people concur about values but disagree about facts presents another easy choice: in this case, experimentation is the order of the day. If the facts are not in question, but people's values are in conflict, then they can negotiate to solve the problem. The most complicated and difficult choices are those where both facts and values are in dispute. In such situations, paralysis or chaos results. Most difficult public policy choices are problems of this type, and the best approach here is to experiment and bring the facts to a point where people no longer dispute them; people can then start to negotiate about values.

REFLECT

Any successful problem solver develops an array of techniques to spark her creative process.

This reflection can be conscious, unconscious, intellectual, intuitive, planned unplanned, or all of the above. The key is to give yourself time to reflect on the problem and let a solution bubble to the top of your consciousness.

When I am faced with a particularly thorny issue, I go for a walk or a run, which stirs my creative juices and removes me from other distractions. You should do what works for you: many people listen to music, make pottery, take a bath, or clean house to attain the focus they need for true reflection.

One of my most successful tricks is to break my normal routine. Some of my best insights have come on airplanes where I have time to reflect and have few of my normal distractions. Go for a walk or a run, ride your bike, or go on a trip. Call a friend you haven't seen in a while. Do something out of the ordinary and forget about the problem for a few hours. Brilliant insights often occur when you're relaxed and not thinking about the problem at all.

If a problem remains daunting, ask if there's some small question that you can answer (jump "into the picture"). Answering that question often results in some obvious follow-up questions that can also be answered, and addressing these usually puts you on the road to a solution.

A time-tested technique for breaking logjams is to describe the problem to someone else. One friend recalled for me how her mother helped her solve math problems in junior high school. "Mom couldn't remember the details about specific math techniques but suggested that I explain the problem to her. By the time I had given her the details I virtually always had a new insight for a solution. Explaining the problem forced me to think clearly."

There is a series of questions that flow through my mind whenever I'm faced with a problem unlike any I've seen before. These questions, largely based on G. Polya's book (How to Solve It), are as follows:
• "What is the unknown" (i.e., the number I am trying to calculate)?
• What data are given, and which can be estimated using knowledge I already have? Are the given data correct based on other knowledge I have? Are there any additional data I can bring to bear on the problem?
• Can I restate the problem in different words?
• Can I draw a picture or graph framing the problem?
• Is there another similar problem I have already solved that could give me the key to a solution? Can I solve a related problem?
• Can I make some simple assumptions that might help me solve the problem more easily? Can I solve just one part of the problem? Can I solve a simplified version of the problem, using round numbers that are roughly right?
• Are there any answers that I know are wrong? (Sometimes you can get closer to an answer by eliminating those that cannot be correct.)

INQUIRE

Quick—your boss just assigned you a task that is outside your area of expertise. What do you do?

My first move is always to pick up the phone. I have friends with a wide range of interests and usually there is at least one with direct knowledge of a particular topic. By asking these people focused questions I can quickly determine what is possible within the time allotted.

BE A DETECTIVE

One of the defining features of the literary character Sherlock Holmes is his scientific approach to solving mysteries. He has an immense store of knowledge of past criminal activity upon which he can rely. He systematically collects information from the scene of the crime and notes seemingly trivial details that might bear upon his case. He does not prejudge the case in advance of the facts. Finally, he is skilled in weaving alternative theories that might fit the facts.

Holmes' approach is not unlike that required to solve problems in the modern world. Any problem solver worth her salt knows as much as possible about data and previous work on the problem at hand (if you're new to it, then go the library and read). Attention to detail is also essential, as is not allowing your initial snap judgments to color your interpretation of parts of the puzzle. And weaving alternative theories to fit the facts is perhaps the most important skill of a seasoned problem solver.

Spreadsheets are my favorite problem-solving tool because they allow me to create many different scenario calculations easily and quickly. Business people use them to create financial projections for their business plans. Scientists use them to analyze data from their experiments. Policy analysts use them to project the effects of proposed government policies on people's lives and on the economy as a whole. In each case, spreadsheets enable both quick scoping calculations and extremely detailed analysis.

When you discover such inconsistencies in your spreadsheets, Holmes' technique of systematically investigating alternative theories comes into play. Begin by making a list of possible reasons to explain why the calculation is in error; then, trace the flow of data through the calculations, starting from the point at which you noticed the inconsistency. Look at each and every input to a particular calculation to see whether you've made any obvious errors in entering formulas or data; trace the calculations all the way back to the beginning. If, as is commonly the case with complicated calculations, you still can't figure out what's wrong, recreate your calculation in a new spreadsheet, usually using a simplified version of the calculation and plugging in data that are roughly right (and that are nice round numbers like 100 or 1,000). This approach allows you to begin with a clean slate. Often when you are immersed in calculations you can forget small details. Starting fresh in this way helps you catch those errors.

Another common technique used by detectives is to consider the motives or interests of the person or institution putting forth a particular viewpoint. I suspect, for example, that a lobbyist for the tobacco industry might be prone to overlook evidence that smoking is harmful. Seek out sources whose interests coincide with the truth, and discount somewhat the opinions of those with a vested interest. However, remember that having an interest or an opinion is not evidence of being biased any more than not having an opinion is evidence of being unbiased: some people (a rare few) are honest even to their own detriment.

CREATE CONSISTENT COMPARISONS

In the real world, so many things change at once that it is often difficult to decipher cause and effect. One of the most compelling techniques for making a point in the face of this complexity is to find or create a consistent comparison that eliminates the complicating factors and illustrates your point in an unambiguous way. A pure consistent comparison is one where the only feature differing between two examples is the one that illustrates your point. Even when there are some minor differences, you can often correct for these and still create a powerful comparison.

Isolating the root cause by creating an experiment is one of the most fundamental techniques of modern science. When medical researchers create "control groups" to compare to people being given an experimental drug, they are creating a consistent comparison or as near to one as is humanly possible. Although you can't always create such an experiment, you can often uncover one if you look carefully.

In 1992, Honda introduced a new Civic hatchback that was the same size and had the same engine power as the model it replaced, but it was 56% more fuel efficient than the previous year's model.

The two cars differed slightly in features but were essentially identical except for their fuel economy. The case was therefore a good one to use to estimate the actual retail costs of improving fuel economy in the real world. After correcting for the costs of the different features (based on dealer cost and list prices), the more efficient Civic (the 1992 VX) cost about $700 more than the 1991 Civic DX, and saved about 110 gallons of gasoline per year for typical drivers. The added cost would pay for itself in about five years at then prevailing fuel prices, making it a cost-effective investment.

The example was an exceptionally powerful one because the size and engine power of the two vehicles were identical, and the feature list was nearly so. As a check on the calculation of the retail cost, we also investigated the projected retail cost of the technologies used to improve the VX's fuel economy, based on independent engineering estimates and found that these estimates were quite close to our calculation of the actual retail cost difference between the 1991 DX and the 1992 VX. This independent check gave us confidence that we were on the right track. The 1993 Civic VX gets about fifty miles per gallon on the freeway yet holds four passengers comfortably. It's not a luxury vehicle by any means, but it's a testament to what automakers can do if they put their minds to it.

TELL A GOOD STORY

The steps for successful scenario development are as follows:

• Define the question: Scenarios should be developed in advance of some major strategic decision so that when the time to decide arrives, the options are laid out in detail and the implications of each decision path are made manifest. Such a decision might be 'Should our company expand into new markets next year, or should we focus on expanding our market share in our current markets?'

• Determine the key factors affecting the system: The next step is to identify the key factors determining whether the focal decision will succeed or fail. These factors might include such things as customer acceptance of a new technology or competitor response to the new strategy. They could also include demographics, inflation, commodity prices, technological change, public policies, or political instability. Some of them are beyond the control of any individual or institution ("predetermined elements"), and others are subject to human influence.

• Evaluate factors by importance and uncertainty: Of the trends and driving forces identified in the previous step, a small number will be both highly important and highly uncertain (see also Morgan and Henrion's book Uncertainty). These are the issues upon which differences in the scenarios will be based. Predetermined elements don't differ among scenarios.

• Choose the scenario set: The most important and uncertain factors should be combined in various ways to define the set of scenarios to be considered. These factors are the dimensions of uncertainty that the scenarios will explore. For example, the scenario set for an analysis of the costs of reducing carbon emissions might include variations in fuel prices and costs of different technologies, which are two of the key sources of uncertainty. One scenario (a worst case for carbon reductions) might combine low fossil fuel prices with pessimistic technology costs for non-fossil sources. Another scenario might combine high fossil fuel prices with optimistic technology costs. The set of scenarios chosen also frames the story lines that will emerge from the scenarios.

• Add detail to the scenarios: Each of the key driving forces and factors from the second step should be assessed for each of the main scenarios. Usually, these factors can be assigned relative rankings (e.g., 'Inflation should be higher than average in scenario 1 and lower than average in scenario 2'), which can then be translated into actual numbers. The exact numbers are not so important as long as they reflect in a credible way people's expectations about how the future might unfold in a particular scenario. The scenario must then be woven into a plausible story describing a course of events that would result in the scenario's final outcome. Each scenario must be named in a way that vividly reminds people of its essence.

• Determine the implications: Revisit the decision identified in step 1, and assess how that decision would fare in each of the different scenarios. If the decision (e.g., expanding into new markets) would lead to success (as defined in step 2) for all or most of the scenarios considered, that decision is probably a wise one. If it is likely to be successful in only one scenario, the decision is "a high-risk gamble . . . especially if the company has little control over the likelihood of the required scenario coming to pass."

• Define metrics for success: Once the scenarios have been developed, it is crucial to identify a few key indicators by which decision makers can monitor the evolution of events. These indicators are used to determine which of the different scenarios best matches up with actual events and can be used to trigger an institutional response (e.g., 'if inflation gets up to 7% important and highly uncertain (see also Morgan and Henrion's book Uncertainty). These are the issues upon which differences in the scenarios will be based. Predetermined elements don't differ among scenarios.

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• Define metrics for success: Once the scenarios have been developed, it is crucial to identify a few key indicators by which decision makers can monitor the evolution of events. These indicators are used to determine which of the different scenarios best matches up with actual events and can be used to trigger an institutional response (e.g., 'if inflation gets up to 7% and the stock market goes down 15%, then do X'). If you can't measure it, you can't manage it, so defining appropriate indicators is crucial to success.

Instead of limiting your imagination by current circumstances and constraints, imagine a world in which some key constraints don't exist, and ask yourself how you or your institution might respond.

DIG INTO THE NUMBERS

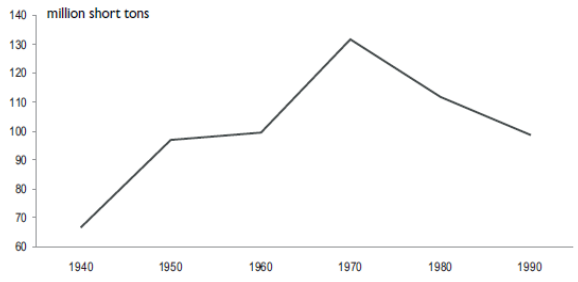
Compare the numbers to something else with which you are familiar, as a "firstorder" sanity check. These comparisons can show you whether or not you are on the right track. Presenting such comparisons in reports and talks can also increase your credibility with your readers or listeners because it shows that your results "pass the laugh test."

Normalize numbers to make comparisons easier.

For example, the true size of total U.S. gross national product (GNP) in trillions of dollars per year is difficult to grasp for most people but if normalized to dollars per person per year will be a bit more understandable. Common bases for such normalizations are population (per person or per capita), economic activity (per dollar of GNP), or physical units of production (per kilowatt hour or per kilogram of steel produced).

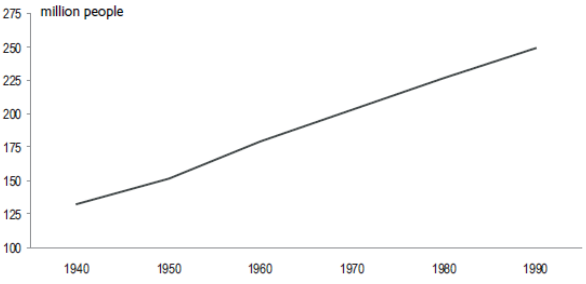
If you have information that extends over time ("time series data"), normalize it to a base year to enhance comparisons. By expressing such data as an index (e.g., 1940 = 1.0), you can compare trends to those of other data that might be related. For example, if you plot U.S. raw steel production (Figure 27.1), population (Figure 27.2), and GNP (Figure 27.3) in separate graphs, it is difficult to gain perspective on how fast steel production is changing over time relative to these other two important determinants of economic and social activity.

FIGURE 27.1. U.S. production of raw steel 1940-1990 [58]



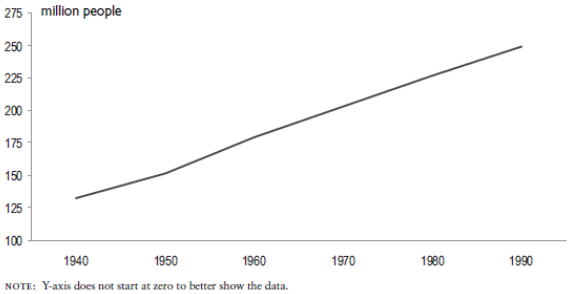
NOTE: Y-axis does not start at zero to better show the data.

FIGURE 27.2. U.S. population 1940-1990 [59]



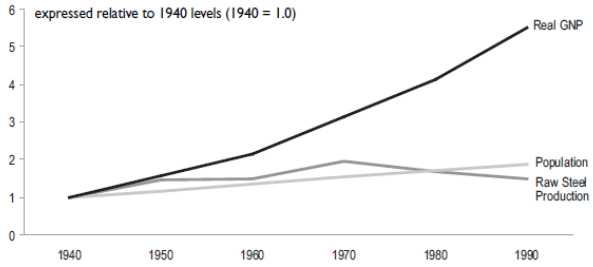
NOTE: Y-axis does not start at zero to better show the data.

FIGURE 27.2. U.S. population 1940-1990 [59]



NOTE: Y-axis does not start at zero to better show the data.

FIGURE 27.4. U.S. raw steel production, population, and gross national product 1940-1990



However, if you plot steel production over time as an index with 1940 = 1.0 (see Figure 27.4), you can plot population and GNP on the same graph. Such a graph will instantly show whether growth rates in the data differ. In this example, real GNP grew by a factor of more than five from 1940 to 1990. U.S. steel production roughly doubled by 1970 and then declined by 1990 to roughly 50% above 1940 levels. The population in 1990 just about doubled from 1940 levels. The trends for U.S. steel production in Figure 27.4 dramatically illustrate the changing fortunes of steel in a postindustrial economy.

Break problems into component parts.

Explore analysis results by examining the factors that led to those results. For example, suppose someone tells you that the market capitalization of Google in November 2007 was about $226 billion and that of General Electric (GE) was $412 billion. What steps should you take to understand what these numbers mean?

Market capitalization is the product of the number of shares outstanding and the stock price per share, as shown in the following equation:

Market Capitalization ($) = # Shares × Stock Price / Share

The stock price per share can be further broken down into the product of the earnings per share and the price-to-earnings ratio, yielding the following simple model:

Market Capitalization ($) = # Shares × Earnings / Share × Price / Earnings

The product of the number of shares and the earnings per share gives the total annual earnings (profits) for each company. Substituting in the previous equation, we get:

Market Capitalization ($) = Total Earnings × Price / Earnings

If we divide both sides of this equation by annual revenues, we get

Market Capitalization / Annual Revenues = Total Earnings / Annual Revenues x Price / Earnings

All of these equations represent variations on the same model. Different forms of the model will be useful at different times. We chose the last version of the model for the discussion below because we can ascribe real meaning to the business factors affecting the two terms in that model. For most companies, the basic information for the model is readily available on the Web, so that is the best place to start (you could also go to the library). Table 27.1 summarizes the key financial parameters for calculating market capitalization for the two companies.

TABLE 27.1. Comparison of financial statistics for Google and General Electric (GE)

	Units	*GE*	*Google*	*Ratio Google /GE*
Annual revenues	B$ 2007	174	15.0	0.086
Number of shares	Billions	10	0.3	0.03
Price per share	$2007/share	40	722	18
Diluted Earnings per share (EPS)	$2007/share	2.2	12.8	5.9
Trailing price-to-earnings (PE) ratio	Ratio	19	56	3.0
Total earnings	B$ 2007	22	4.0	0.18
Earnings per dollar of revenues	$/dollar	$0.13	$0.26	2.1
Market capitalization	B$ 2007	412	226	0.55
Market cap. per dollar of revenues	$/dollar	$2.4	$15	6.4

(1) B signifies billions (thousand millions for British readers).
(2) PE is the share price to earnings ratio.
(3) Market capitalization (measured as an intraday value) is the product of # of shares and price per share. Price per share is the product of EPS and PE ratio.
(4) Values taken from Yahoo! Finance on November 4, 2007.

The first thing to notice about the financial statistics for these two companies is a huge disparity. While GE's market capitalization in November 2007 was about twice as large as Google's, GE's revenues were almost twelve times larger. All other things being equal, we might expect that companies with similar market valuations would also have similar revenue streams. All other things are not equal, however, and finding out why will help illustrate this important analytical technique.

If Google's market capitalization per dollar of revenues was the same as GE's, we would expect that its market capitalization would be only one-sixth as large as it is and we need to explain this six-fold discrepancy. To do so, we examine the components of the last equation above. The first component is earnings per dollar of revenues, and the second component is the price-to-earnings ratio.

As Table 27.1 shows, Google's earnings as of November 2007, were about twice as big as GE's per dollar of revenues, which accounts for about a factor of two in our six-fold difference. The price-to-earnings ratio also differed between the two companies. Apparently, the stock market valued one dollar of Google's earnings three times as much as one dollar of GE's earnings, which accounts for the remaining difference.

By breaking these numbers into their component parts, we have been able to isolate the two key reasons for the sixfold discrepancy identified above. The next step is to explain why these two reasons exist. Google's greater profitability per dollar of revenue reflects the difference between industrial manufacturing and Internet software development. The latter has very low marginal costs of reproducing the product and high gross margins.

Google's higher price-to-earnings ratio reflects the market's belief that its dominance in Internet technology will allow the company to continue to generate growth in earnings at a pace vastly exceeding that of traditional industrial enterprises.

Dissecting analysis results by comparing ratios of key parameters is a powerful approach, and one to use frequently. Any time you have two numbers to compare, this kind of “ratio analysis” can lead to important insights into the causes of underlying differences between the two numbers.

Creating a presentation or an executive summary for a complex report always involves boiling an analysis down to the essentials. First, create equa-tions (like the ones above) that calculate key analysis results as the product of several inputs multiplied together. Then, determine which of these inputs affects the results most significantly. Creating such models can help you think systematically about your results.

APPLYING THESE LESSONS

Let's look at a specific example to make this advice more real. The web site <http://www.stateline.org> has time series data by state for a variety of items, including educational and environmental expenditures as well as tax revenues.

CONCLUSIONS

When John Holdren was a professor at UC Berkeley, he taught a class called "Tricks of the Trade," in which he listed key pitfalls to avoid in data acquisition and handling. I have aggregated them below into four golden rules:

• Avoid information that is mislabeled, ambiguous, badly documented, or otherwise of unclear pedigree. Ambiguity and poor documentation are an indication that the quality control for such data is uneven at best and appalling at worst. Dig into the numbers a bit and find out whether it's carelessness or incompetence; make sure you believe the numbers before using them.

• Discard unreliable information that is invented, cooked, or incompetently created. If you find major inconsistencies, conceptual flaws, and omissions in the data, you'll need to discard that information, no matter how much it might help your analysis.

• Beware of illusory precision. Don't represent or interpret information as more accurate than it is. Carefully characterize uncertainty and variability in your data, and insist that others do so with their own.

• Avoid spurious comparability. Beware of numbers that are ostensibly comparable but are actually inconsistent. Create and use only consistent comparisons.

MAKE A MODEL

People are often intimidated by the use of computer models to conduct an analysis, but never forget that these models depend on data and assumptions that are based in large part on analysts' judgment. It is a rare model that does not contain dozens or hundreds of such assumptions; in fact, these data and assumptions determine the outcome in many cases. This heavy reliance on assumptions for parameters that are unknown is most prevalent in models used in business and public policy, but even models of the physical world can rely on assumptions that influence or determine the outcome.

There are some models, especially some science and engineering models, that are large or complex because they need to be. But many more are large or complex because their authors gave too little thought to why and how they were being built and how they would be used.

Don't be too impressed by a model's complexity. Instead, ask about the data and assumptions used to create scenarios. Focus on the coherence of the scenarios and their relevance to your decisions, and ignore the marketing doublespeak of those whose obsession with tools outweighs their concern with useful results. Sadly, many modelers fall into this latter camp, and you would do well to avoid their work.

REUSE OLD ENVELOPES

For virtually any problem, it is possible to create an approximate solution using information you now or can estimate from daily life experience. Most people don't believe this until they try it a few times, but it's true.

A business plan for a new venture, for example, usually involves dozens of such smart guesses about sales of a product, costs of sales, overhead, and other parameters. The first draft of such a plan is essentially a back-of-the-envelope calculation that will later be refined and improved in discussions with experienced business people.

People involved in fast-moving new ventures usually don't have time to research issues thoroughly and don't have money to hire someone to do it for them (sometimes even the people they hire don't have time either!). Often, back-of-the-envelope calculations are the best that can be done in the time allotted. The law of averages keeps the accuracy of such calculations from deteriorating too much because you are just as likely to overestimate as to underestimate (assuming that you're not biased one way or another). Across all the assumptions you make, these deviations average out.

Another simple but powerful tool in back-of-the-envelope calculations is called “unit analysis.” Think of the calculation we did above to determine the cost of oil in $/liter.

Whether the problem concerns cooking, automobile repair, or personal relationships, there are two basic types of responses: the fainthearted turn to authority–to reference books, bosses, expert consultants, physicians, ministers–while the independent of mind delve into that private store of common sense and limited factual knowledge that everyone carries, make reasonable assumptions, and derive their own, admittedly approximate, solutions.
— HANS CHRISTIAN VON BAEYER

USE FORECASTS WITH CARE

In evaluating forecasts of exponential growth rates, an important trick is known as “the rule of 70.” If you have an annual growth rate (say 2% per year for U.S. population) then the time it will take (in years) for population to double is roughly 70 or thirty-five years. Growth of 7% per year implies a doubling time of about ten years. You don’t need to know why this works, you just need to remember it. Why is a doubling time useful? It is much easier to calculate multiples of two than to actually calculate exponential growth in the formal way. When only an approximate number is needed, a doubling time is good enough. Say you want an approximate estimate of how much $10,000 now will be worth when you retire. If the growth rate after inflation is 7%/year (a reasonable long-term estimate for money invested in a tax-deferred stock account) the doubling time is ten years. In 30 years, the money will have undergone three doublings, or a factor of eight increase (2 x 2 x 2), and will be worth about $80,000 in 1997 dollars (of course, you’ll have to pay taxes on that money when you withdraw it).

THE LOGISTIC CURVE
Many phenomena in nature and in business are described by the so-called “logistic curve” (also known as the “S curve”). This curve (shown in Figure 30.1) is characterized by slow but rising exponential growth in the early phase, rapid growth in the middle phase, and growth that tapers off as fundamental limits are reached (see Ecoscience). The logistic curve describes most phenomena eventually and applies equally well to technology adoption and population growth. We don’t know where the top limits are in many cases, but in cases where we can identify those upper limits, the concept can come in handy.

If forecasts are part of your planning process, don’t create just one. Instead, use a set of forecasts (i.e., scenarios) to explore the future. Vary key factors, and investigate which of them to ignore and which to dissect further. All forecasts are wrong in some respect, but if the process of designing them teaches you something about the world and how events may unfold, creating them will have been worth the effort.

HEAR ALL SIDES

One of the first rules of management in dealing with a conflict between coworkers is to listen carefully to all sides of the story before saying or doing anything.

Formal debates in the Oxford style, sponsored by a British organization called “Intelligence Squared” and its US counterpart, have become popular recently (circa 2007). Each debate addresses a specific proposition like “global warming is not a crisis” with two skilled debate teams taking opposite sides of the issue. The audience is polled before and after the debate, and the team that manages to move more of the audience to its side than it had before the debate is declared the winner. Of course, the way that the proposition is initially framed can have a big influence on the quality of the discussion.

In the academic world, there is a tradition of “brown bag lunches” where researchers present work-in-progress to friends and close colleagues. These lunches help identify problems with analysis before a paper is written or presented to a wider group. They work best when all concerned are on friendly terms and the objective of clarifying the key argument is accepted by all participants.

KNOW YOUR AUDIENCE

If oil drilling in the Arctic National Wildlife Refuge was a hot topic before congress that day, he would express his energy savings estimates in terms of “Arctic Refuges saved.”

If the public utility commissioners were concerned about canceling a power plant construction project, Art would calculate how much the savings were worth in terms of “avoided power plants.” And for the lay audience, Art would show how much money people would save per household if they bought the better fridge. In each case, Art’s message gained resonance because he thought seriously about the concerns of the audience.

In both talks and papers, your audience will only retain a few key points from your work. You must decide what those few points should be, and hammer them home. If you don’t, you risk not reaching the people you set out to convince. So step back and reflect after you’ve completed your analysis. Think about what you’ve learned, and explain it in three or four simple sentences. Dig into the numbers to support your main points, but don’t overwhelm your audience with numbers. Instead, focus on the conclusions, describe why your analysis makes such a compelling case, and explain it in ways specifically tailored to reach your audience.

This lesson is particularly important when the analysis results are intended to affect public opinion or a public policy debate. Journalists generally latch on to only a few key results of a complex study when deciding what “angle” to take with a story. Express these results to reach out to the desired audience, and your effectiveness will increase many times over.

DOCUMENT, DOCUMENT, DOCUMENT

Over the years, friends have clipped dozens of articles for me on topics in which they knew I had an interest. In almost all cases, they neglected to write on the clipping the full reference, thus rendering it unusable for research purposes. An article without a reference is useless except as background info. An article with a reference is a citable source.

Documentation lends credibility to any intellectual effort. It also recognizes the previous work of others and allows readers to follow your thought processes (it also allows YOU to recreate your thinking months after you have achieved some conceptual breakthrough). Any competent analyst ought to be able to recreate your analysis from the documentation you provide, and you must be able to do the same more quickly than others can. Finally, the process of documenting your results can help you check those results and ensure accuracy.

Documentation is one of Stephen Covey’s “important but not urgent” tasks and one that should be a priority in any analysis work.

TAKE RESPONSIBILITY FOR YOUR WORK

When documenting or writing reports, take responsibility by using the active voice. For example, say “I estimated the following parameters” instead of “the following parameters were estimated.” Make it crystal clear who did what, so there is no ambiguity. The passive voice is the tool of people who want to avoid responsibility for their actions, but the purpose of documentation is to assign responsibility, for all the reasons listed above. Don’t thwart your efforts by using the often ambiguous passive voice.

Any time there is a new “hot” analysis topic, people with little prior knowledge jump in. You can perform an immense service to any debate (and garner attention for your point of view) simply by being systematic in identifying and investigating such topics and documenting them in a careful way. A case in point is the raucous debate over the cost of pollution to society from power plants during the late 1980s and early 1990s. In 1990, I wrote a paper that was not a conceptual breakthrough but simply created consistent comparisons among different estimates of these social costs.

Don’t just write to be understood; write so that you cannot be misunderstood.
— ROBERT LOUIS STEVENSON

The main purpose of writing of this type is to present, in as clear a fashion as possible, the logic of the calculations, the main input data, and the key results. Any competent analyst ought to be able to reproduce your analysis using the documentation contained in your report. If they can’t, your work isn’t done. An astounding number of analysts routinely omit vital data and assumptions from their reports, a practice for which there can be no excuse.

CREATE COMPELLING GRAPHS AND FIGURES

Tufte defines graphical excellence as “that which gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space.” He promotes several rules that will help you avoid the most common

pitfalls, which I summarize below:

• “Above all else show the data”: Make sure the graphs highlight your results instead of hiding them as many graphs do. Use the graphs to tell stories about your analysis, and make those stories leap out at the reader.

• “Maximize the data-to-ink ratio, within reason”: Tufte defines the dataink ratio as the amount of ink that conveys information divided by the total amount of ink used for the graph. Many graphs have low data-ink ratios, and you should avoid this pitfall. To maximize the data-ink ratio, “erase non-data-ink and redundant data-ink.”

• “Eliminate chart junk”: Remove clashing fill patterns (Moiré patterns), which are hard on the eyes. Eliminate extraneous gridlines, which obscure the data. Delete graphical elements that decorate but convey no information, such as 3-dimensional (3-D) chart elements on 2-D graphs.

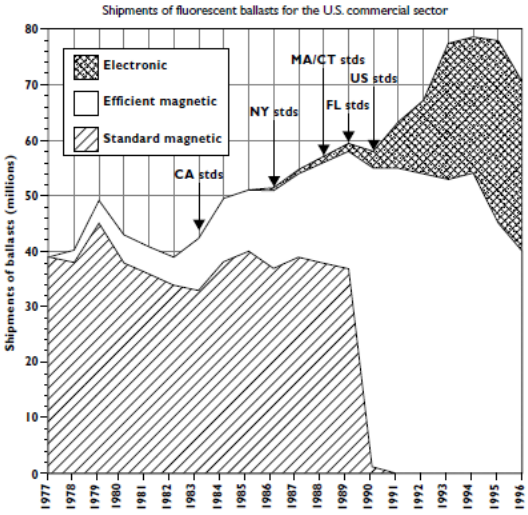
• “Maximize data density” (numbers per unit area), within reason: Typical graphs in newspapers and journals, based on Tufte’s review of hundreds of charts published 1970-1980, have data densities of 5 to 20 numbers per square inch (0.8 to 3 numbers per square centimeter). The densest graph Tufte examined (a map of galaxies contributed by some astronomers) had a data density of 110,000 numbers per square inch (17,000 numbers per square centimeter); the least dense graph he considered had a data density of 0.15 numbers per square inch (0.02 numbers per square centimeter). Maps tend to have high data density; badly designed charts tend to have the lowest. When things get really bad, a graph may contain only one data point.

• “Use small multiples”: One important way to maximize data density is to create what Tufte calls small multiples, defined as “a series of graphics, showing the same combination of variables, indexed by changes in another variable.”78 Let’s say you plot monthly rainfall for Mobile, Alabama, as shown in Figure 35.4. If you have data on rainfall for many cities that you’d like to compare, you can shrink them and plot them side by side, as shown in Figure 35.5. You need not reproduce all of the labels on every chart. Once the reader has learned the “key,” small multiples like these allow quick and easy comparison of large amounts of data. For many more examples of this technique, see Chapter 11 of Show Me the Numbers (“Design Solutions for Multiple Variables”).

• “Revise and edit”: All work improves with revisions. Leave enough time to get feedback and make your graphs better.

• Make figures stand alone. Figures are often copied separately from the report in which they appear, to allow the reader to trace your figure back to the source. Put the date and file name on the figure, at least when it’s in draft form.

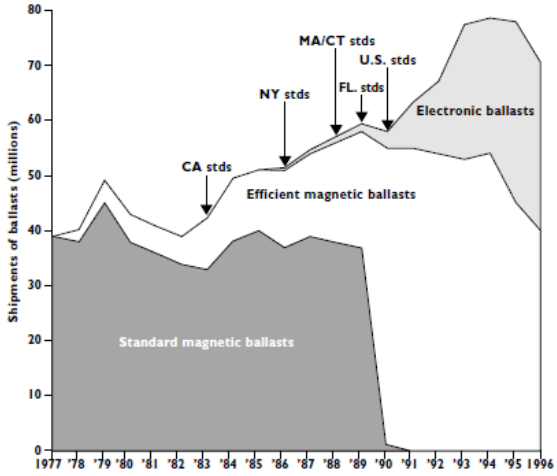
FIGURE 35.6. A graph that needs work



NOTE: Because they are not typically used in the commercial sector, the following ballast types are omitted from the data presented in this figure: low-power-factor ballasts (shipments of 24.2 million in 1996), 1500 MA high-power-factor ballasts (0.2 million in 1996), and ballasts included in the "All other corrected power factor" category of the Census Bureau data. Ballast imports are not included because they were not disaggregated by ballast type in the census data. Arrows indicate the years in which state standards and, finally, federal standards took effect, preventing the sale of standard magnetic ballasts.

SOURCES: Koomey et al. (1995); Census Bureau MQ36C(94)-5, Table 3; Census Bureau MQ36C(96)-5, Tables 3 and 4

FIGURE 35.7. An improved graph



NOTE: Because they are not typically used in the commercial sector, the following ballast types are omitted from the data presented in this figure: low-power-factor ballasts (shipments of 24.2 million in 1996), 1,500-MA high-power-factor ballasts (0.2 million in 1996), and ballasts included in the "All other corrected power factor" category of the Census Bureau data. Ballast imports are not included because they were not disaggregated by ballast type in the census data. Arrows indicate the years in which state standards and, finally, federal standards took effect, preventing the sale of standard magnetic ballasts.

SOURCES: Koomey et al. (1995); Census Bureau MQ36C(94)-5, Table 3; Census Bureau MQ36C(96)-5, Tables 3 and 4.

CONTACT: Jonathan Koomey, JGKoomey@lbl.gov. <http://enduse.lbl.gov>

FILENAME: Final Ballast Charts

DATE OF CREATION: February 1995.

DATE OF LAST MODIFICATION: October 1997.

Figure 35.7 is the improved version of the graph, which has a higher data-to-ink ratio than does Figure 35.6 and is easier to read. I eliminated the Moiré vibration by using shades of gray and white and eliminated the legend by using labels directly on top of the appropriate areas of the graph. I removed the gridlines as well as the box around the graph and reduced the number of tick marks on the Y-axis to only the major ones. I shrank the type size of the years along the X-axis and shifted to a different convention of representing the years ('94 instead of 1994) for all years but the first and last (another choice would have been to lay out the graph in landscape format so that the X-axis was longer). I also changed the figure caption to reflect the main story that the graph tells. Finally, I added author's contact information, the file name, and the dates of creation and last modification for the file.

TABLE 36.1. A table with issues

YTD International Revenue

Product	Jan	Feb	Mar	Apr	May	Jun	Total
Disk Drives	$93,993.00	$84,773.00	$88,833.00	$95,838.00	$93,874.00	$83,994.00	$541,305.00
Monitors	$87,413.00	$78,838.00	$82,614.00	$89,129.00	$873,020.00	$78,114.00	$1,289,128.00
Printers	$90,035.00	$2,120,400.00	$85,093.00	$91,803.00	$899,210.00	$80,457.00	$3,366,998.00
Computers	$92,736.00	$83,640.00	$87,645.00	$94,557.00	$92,619.00	$82,871.00	$534,068.00
Memory Sticks	$3,624,500.00	$77,785.00	$81,510.00	$87,938.00	$86,136.00	$77,070.00	$4,034,939.00
Sound Cards	$88,832.00	$80,118.00	$83,956.00	$90,576.00	$88,720.00	$79,382.00	$511,584.00
Video Cards	$82,614.00	$74,510.00	$78,079.00	$84,236.00	$82,509.00	$73,825.00	$475,773.00
RAM	$85,092.00	$76,745.00	$80,421.00	$86,763.00	$84,985.00	$76,040.00	$490,046.00
Scanners	$87,645.00	$79,048.00	$82,834.00	$89,366.00	$87,534.00	$78,321.00	$504,748.00
Input Devices	$90,275.00	$81,419.00	$85,319.00	$920,470.00	$90,160.00	$80,671.00	$1,348,314.00
Total	$4,423,135.00	$2,837,276.00	$836,304.00	$1,730,676.00	$2,478,787.00	$790,746.00	$13,096,903.00

TABLE 36.2. The table revised

YTD International Revenue (2008 USD)

Product	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Total*	*% of total*
Memory Sticks	3,624,500	77,785	81,510	87,938	86,136	77,070	$4,034,939	30.8%
Printers	90,035	2,120,400	85,093	91,803	899,210	80,457	$3,366,998	25.7%
Input Devices	90,275	81,419	85,319	920,470	90,160	80,671	$1,348,314	10.3%
Monitors	87,413	78,838	82,614	89,129	873,020	78,114	$1,289,128	9.8%
Disk Drives	93,993	84,773	88,833	95,838	93,874	83,994	$541,305	4.1%
Computers	92,736	83,640	87,645	94,557	92,619	82,871	$534,068	4.1%
Sound Cards	88,832	80,118	83,956	90,576	88,720	79,382	$511,584	3.9%
Scanners	87,645	79,048	82,834	89,366	87,534	78,321	$504,748	3.9%
RAM	85,092	76,745	80,421	86,763	84,985	76,040	$490,046	3.7%
Video Cards	82,614	74,510	78,079	84,236	82,509	73,825	$475,773	3.6%
Total	$4,423,135	$2,837,276	$836,304	$1,730,676	$2,478,767	$790,745	$13,096,903	100%

In the redesigned version (Table 36.2), the non-data ink has been removed, the dollar signs have been deleted (except for the totals), the numbers have been lined up by decimal points, the extraneous ".00" at the end of each number has been removed, and the categories have been ranked in decreasing order by the total. Finally, an additional column calculating the percent of the total has been added to aid reader comprehension.

TABLE 36.3. A table in one of my group's reports that needs revision

U.S. Shipments and Imports of Lamps, 1983-1994

Year	U.S. Shipments (millions of lamps)	Imports (millions of lamps)
1983	3615.9	560.9
1984	3723.4	748.7
1985	3472	862.7
1986	3421.3	920.6
1987	3399.4	999.8
1988	3510.2	1130.8
1989	3429.5	1024
1990	3318.5	1051
1991	3297.5	Data unavailable from Census Bureau
1992	3422.1	Data unavailable from Census Bureau
1993	3564.3	1372.6
1994	3563.3	1577.8

NOTE: "U.S. shipments" refers to total shipments by manufacturers located within the U.S., including units to be exported. Cold-cathode fluorescent lamps are excluded from the U.S. shipment data; Christmas tree lights are excluded from U.S. shipments as well as imports.
SOURCE: Census Bureau current industrial reports MQ36B, various years.

TABLE 36.4. Revised and improved version of Table 36.3

U.S. Shipments and Imports of Lamps, 1983-1994

	U.S. Shipments		*Imports*		
Year	Millions of lamps	Index 1983 = 1.00	Millions of lamps	Index 1983 = 1.00	Imports as a % of U.S. shipments
1983	3,616	*1.00*	561	*1.00*	16%
1984	3,723	*1.03*	749	*1.33*	20%
1985	3,472	*0.96*	863	*1.54*	25%
1986	3,421	*0.95*	921	*1.64*	27%
1987	3,399	*0.94*	1,000	*1.78*	29%
1988	3,510	*0.97*	1,131	*2.02*	32%
1989	3,430	*0.95*	1,024	*1.83*	30%
1990	3,319	*0.92*	1,051	*1.87*	32%
1991	3,298	*0.91*	NA	*NA*	NA
1992	3,422	*0.95*	NA	*NA*	NA
1993	3,564	*0.99*	1,373	*2.45*	39%
1994	3,563	*0.99*	1,578	*2.81*	44%
Average annual % change 1983–1994	-0.1%		9.9%		10.0%

NOTE: "U.S. shipments" refers to total shipments by manufacturers located within the U.S., including units to be exported. Cold-cathode fluorescent lamps are excluded from the U.S. shipment data; Christmas tree lights are excluded from U.S. shipments as well as imports.
NA = Not Available
SOURCE: U.S. Census Bureau current industrial reports MQ36B, various years
CONTACT: Jonathan Koomey, JGKoomey@lbl.gov. <http://enduse.lbl.gov>
FILENAME: shipmentsandimports.xls
DATE OF CREATION: February 1996
DATE OF LAST MODIFICATION: November 1997

The second example, shown in Table 36.3 is taken from one of my former group's technical reports. This table slipped through our quality control, but I'm making amends by dissecting it for this example. Note the extraneous gridlines and the lack of indices that would help the reader focus on the key results from the table. Table 36.4 shows how I revised the table. I eliminated all but the essential gridlines and included indices relative to 1983 (which show how much shipments and imports grew from 1983 to 1994). I also added a column with imports

normalized as the percentage of U.S. shipments, to help the reader understand how this important statistic changed over time. In addition, I included a row with the annual average percentage change from 1983 to 1994 because this summary statistic is helpful for understanding long-term trends in the data. Finally, I added information to the footnotes to identify the contact person, the file name, and the dates of creation and last modification for the file.

TABLE 36.5. A table that needs revision from another of our technical reports

Primary energy use in quads: 1973-1997

	1973	*1986*	*1990*	*1995*	*1997*
Buildings	24.1	26.9	29.4	32.1	33.7
Industry	31.5	26.6	32.1	34.5	32.6
Transportation	18.6	20.8	22.6	24.1	25.5
Total	74.2	74.3	84.1	90.7	91.8

SOURCE: Energy use estimates for 1973-95 come from EIA (1996a, Table 1.1, p. 39). Energy use estimates for 1997 come from EIA (1996c).

TABLE 36.6. Improved version of Table 36.5 for use in a summary report

Primary energy use in quads: 1973-1997

	1973	*1986*	*1990*	*1995*	*1997*	*Average annual change 1973-1997 % per year*
Buildings	24.1	26.9	29.4	32.1	33.7	1.4%
Industry	31.5	26.6	32.1	34.5	32.6	0.1%
Transportation	18.6	20.8	22.6	24.1	25.5	1.3%
Total	74.2	74.3	84.1	90.7	91.8	0.9%
Index (1973 = 1.00)	*1.00*	*1.00*	*1.13*	*1.22*	*1.24*	

SOURCE: Energy use estimates for 1973-95 come from EIA (1996a, Table 1.1, p. 39). Energy use estimates for 1997 come from EIA (1996c).

CONTACT: Jonathan Koomey, JGKoomey@lbl.gov. <http://enduse.lbl.gov>

Table 36.5 shows a third example, taken from another technical report that my group worked on.83 In this case, the client insisted on a particular format for the table, but Table 36.6 shows how I'd change the table if it were up to me (it's not bad, but it could be better). To improve it, I added a column containing the average annual percentage change from 1973 through 1997. I also added a row with an index relative to 1973, which (for example) shows at a glance that primary energy use in the U.S. grew 24% over this period. Finally, I added contact information, so readers with questions know whom to approach. The more detailed information with the file name and date of creation and last modification makes sense for a technical table but would be excessive for a summary table.

TABLE 36.7. Improved version of Table 36.5 for use in a detailed technical report

Primary energy use: 1973-1997

	1973	1986	1990	1995	1997
	Quadrillion Btus of primary energy				
Buildings	24.1	26.9	29.4	32.1	33.7
Industry	31.5	26.6	32.1	34.5	32.6
Transportation	18.6	20.8	22.6	24.1	25.5
Total	74.2	74.3	84.1	90.7	91.8
	Sectoral energy as a percent of total				
Buildings	32%	36%	35%	35%	37%
Industry	42%	36%	38%	38%	36%
Transportation	25%	28%	27%	27%	28%
Total	100%	100%	100%	100%	100%
	Index 1973 = 1.00				
Buildings	1.00	1.12	1.22	1.33	1.40
Industry	1.00	0.84	1.02	1.10	1.03
Transportation	1.00	1.12	1.22	1.30	1.37
Total	1.00	1.00	1.13	1.22	1.24
	Average annual percentage change since 1973				
Buildings	0%	0.8%	1.2%	1.3%	1.4%
Industry	0%	-1.3%	0.1%	0.4%	0.1%
Transportation	0%	0.9%	1.2%	1.2%	1.3%
Total	0%	0.0%	0.7%	0.9%	0.9%

SOURCE: Energy use estimates for 1973-95 come from EIA (1996a, Table 1.1, p. 39). Energy use estimates for 1997 come from EIA (1996c).
CONTACT: Jonathan Koomey, JGKoomey@lbl.gov. <http://enduse.lbl.gov>
FILENAME: primaryenergyuse.xls
DATE OF CREATION: January 1999
DATE OF LAST MODIFICATION: December 1999

Stephen Few, author of Show Me the Numbers: Designing Tables and Graphs to Enlighten, suggests that business practitioners develop standards for graphical display. According to Few, such standards should:
• have effective communication as their primary objective;
• evolve freely as conditions change or new insights are gained;
• be easy to learn;
• save time;
• be applied to the software that is used to produce tables and graphs in the form of specific guidelines and design templates.

Graphics should serve your arguments. If they don't support your analysis in a direct and understandable way, they should be ruthlessly deleted or drastically modified.

CREATE GOOD TABLES

Agood table is a work of art while a bad one is worse than useless. I have worked to refine my table-making skills over the years, and I am constantly amazed at the perfectly dreadful tables created by authors who should know better. Tables are the heart of a technical report, and care in their creation is one sign of a clear-thinking analyst. A little care can make your tables a resource that your readers keep as a reference for many years.

I follow several key principles in creating a table:

• Make them stand alone: Tables are often copied separately from the report from which they came. Make sure the reader can trace your table back to the source (or at least to the author) and that your calculations are explained clearly in the footnotes.

• Create extensive footnotes: This aspect of documentation is crucial. Footnotes to the table should explain the methodology, list the key sources, and describe how each source was used. Any intelligent person should be able to recreate the table from your footnotes. Tufte says that footnotes indicate "care and craft," and readers will be grateful when you create them. Of course, for tables appearing in more popular publications (like newspapers) the standards for footnote documentation are often lower, but even if the footnotes don't appear in the printed version, the person who created the table should still have the footnotes filed away in case there's a need to check the calculations later.

• "Maximize the data-ink ratio," within reason: Edward Tufte's guidance is just as relevant for tables as for graphs. Make sure that every part of the table conveys information. Avoid extraneous gridlines (only include them when they enhance reader comprehension). Use carefully chosen white space to separate and group results.

• Some redundancy is good: Unlike in graphs, where redundancy should generally be avoided, showing additional columns or rows for totals and subtotals is essential. These ostensibly redundant sums help the reader follow the calculation and assure that the table is internally consistent. The sums can also help in troubleshooting your own calculations. Another important redundancy relates to percentages. If you have a column of percentages, label the column heading "% of total" AND put a percent symbol in every cell (e.g., 1.37%, not 1.37). Sometimes people make mistakes in their calculations and forget to divide by 100 to make a real percentage. By enforcing this redundancy, you guarantee that readers will interpret your results correctly and you'll save them time. Having the % symbol in every cell makes the meaning unambiguous.

• Enhance readability with font, style, and orientation choices: In her Non-Designer's Design Book, Robin Williams demonstrates the principles of proximity, alignment, repetition, and contrast, and applies them to everyday design problems. Use spacing, justification (center, left, or right), grid lines, italics, and bold-facing to implement these principles within the table. Align decimal points within each column to add even more information.

• Enhance reader comprehension: The single most important tool to increase usefulness of tabular data is to add rows or columns containing indices relative to a total or subtotal, which will show the relative importance of specific numbers relative to these totals

• Normalize data to facilitate comparisons: It's often helpful to normalize results on a per capita or per GDP basis, so the reader can compare them to more familiar quantities.

• Create the table first; then, write your text from the tables: Creating the tables helps you think through the analysis and ensures that your logic is both correct and reproducible.

Although some aspects of creating good tables are matters of style and preference, the principles described above should remain foremost in your mind, because they are valid for almost every table. Readers should treasure your tables for their accuracy and completeness. Sloppy tables sap your credibility—avoid them at all costs.

USE NUMBERS EFFECTIVELY IN ORAL PRESENTATIONS

Common doctrine is that data are dull. But as Edward Tufte points out, "if the statistics are boring, then you've got the wrong numbers" (or perhaps you are conveying them in a boring way). You should use numbers to tell a story or make an important point. If your audience is not yet convinced, then you are responsible for presenting

the relevant information in a way that is engaging to them. Data are dull only when chosen poorly and presented badly.

Chip and Dan Heath, in their book *Made to Stick*, describe how some messages resonate and others fall flat. The ones that people remember are simple, unexpected, concrete, credible, emotional stories. They cite President Kennedy's goal of having a man walk on the moon within a decade and returning him safely to earth as the archetypal sticky idea. It was simple for people to understand, unexpected in its audacity, concrete and specific, credible because of the President's commitment of resources, and emotionally resonant with Americans' vision of themselves as intrepid explorers.

Gerald Jones, in his book How to Lie with Charts, gives guidelines on the size and kind of text to use in presentations and describes the conventions for measuring font size and spacing. He quotes the Society of Motion Picture and Television Engineers, who recommend that the minimum height of small letters used in on-screen text should be 2.5 percent of the height of the screen. Typical presentation screens are 1.5 meters (5 feet) in height, so the minimum font size in such a screen should be about 4 centimeters (1.5 inches). These guidelines don't just apply to text presentations. Make sure the labels on your tables and graphs are just as readable as your bullet points.

A successful speaker always thinks carefully about the following questions:
• Who will be in the audience?
• What is important to them?
• What are the three key messages you want people to learn from your talk?
(With rare exceptions, that's all they will ever take away.)

SHARE AND SHARE ALIKE

Data 360 <http://www.data360.org<>: This site allows easy posting of data as well as graphing of those data. It explicitly focuses on sharing of public data, but also allows companies to post their own data for a fee. It seems to tilt towards the expert model—I wasn't able to find any way to comment on or change data sets posted by others, although the site hints that people other than the creator can update data.

Freebase <http://www.freebase.com>: Freebase, a product of Metaweb technologies, is described by its developers as an "open database of the world's information". It is a well-funded startup company, and has developed a sophisticated way of using on-line databases that incorporates characteristics of both the wiki and expert models. It's still in Alpha as of this writing, but it shows great promise. It doesn't allow graphing of data within the site, but gives users the ability to grab any data from Freebase and use it in other applications.

Google Base <http://base.google.com>: Google base allows you to post data in more than a dozen predefined item formats (called "types"), including job advertisements, vacation rentals, recipes, products for sale, real estate, events, or personal ads (among others). You can also define your own data type, assuming it's not a particularly complex one. If your data can be structured in a straightforward way, Google Base will make it easy to post it (and by extension, easy for people to find your information using Google's search engine). You can even upload data continuously or in bulk. There is no graphing of data in Google Base, and no way for a user to correct or modify data posted by others.

CONCLUSION

Of primary importance from this book are the following lessons:
• Don't be intimidated by anyone: The key issues surrounding all but the most technical topics can be understood by any intelligent and sufficiently diligent person.

• Be a critical thinker: Dissect your own arguments and those of others. Identify the premises and the main conclusion of each argument. Make sure the premises are acceptable, relevant, and adequate to support the conclusions. Finally, search for missing arguments and for counter arguments.

• Don't confuse what's countable with what really counts: Many of the most important things in life can't be quantified, so don't focus just on the numbers– they aren't everything.

• Get organized: Clean up your office. Establish a filing system that allows you to find what you need when you need it. Buy the key books in your field, and make them accessible. Above all, remember that organization often beats brilliance!

• Question authority: Maintain a healthy skepticism of other people's analysis, and ask questions until you understand their points. Clearly distinguish facts from value judgments, and make sure that others do so too. Don't believe everything you read.

• Dig into the numbers: Look for internal contradictions, large differences, obvious trends, and cognitive dissonance. Compare results to independent sources. Take ratios of numbers, and make sure they relate in a predictable way.

• Focus on the essential: In creating your analysis, focus on designing consistent comparisons, developing credible scenarios, and using simple and understandable models to illustrate the key issues. Avoid complex computer tools unless absolutely necessary.

• Document, document, document: Documentation creates a trail for you and others to follow after the analysis is done. It is essential to any intellectual work but is oft neglected. By making it a priority, you ensure that your intellectual contribution will remain important and useful for years to come.

• Use the Internet: Rely on the Internet to conduct your research, share your data, and make your publications widely available. The old ways of publishing and disseminating data are rapidly being swept away by electronic media, so use these media to full advantage.

• Remember that others don't care as much about your work as you do: It's your responsibility to know your audience, address their concerns, and explain your work in an understandable way. Make your figures clear and compelling, your tables well documented, and your reports so valuable that your colleagues will treasure them for years.

• Synthesis follows analysis: Combining analysis results from different fields in creative ways often leads to new insights. Such synthesis is one powerful way to increase your understanding of the world around you. Don't underestimate its importance.

CONCLUSIONS

People with integrity are the ones who succeed in the long run. The question remains, however: how can you best develop analytical and personal integrity? I offer these final thoughts:

• Say what you mean and mean what you say. If you promise something, always follow through—the recipient will reward your diligence when you need help next time.

• Stick close to the data. Don't make claims the data don't support, and don't let others do so. Never exaggerate, distort, or dissemble, or the results will come back to bite you in the butt (which is a more colorful way of rephrasing Ringer's "Theory of Reality").

• Assume that others will replicate your work. If it's interesting and important enough they surely will, so document it well and be accurate in the claims you infer from it.

• Focus on completing the mission. We've all encountered people whose personal issues, biases, and interests win out over the larger goals, and those are people to avoid if you can. True professionals can properly handle personal interests in a way that still leads to the best outcome for the team as a whole, but such professionals are the exception rather than the rule. You should be such an exception.

NUMBERS TO KNOWLEDGE "TOP ELEVEN" LIST

Choosing my eleven favorites from the "Further Reading" section was not an easy task (I couldn't keep myself to just ten). I know you won't be disappointed with any of these:

1. Huff, Darrell. 1993. How to Lie with Statistics. New York, NY: W. W. Norton & Co., Inc. If this book doesn't make you a skeptical observer of numbers and statistics, nothing will. First published in the 1950s, it's still fresh and useful today.

2. Booth, Wayne C., Gregory G. Colomb and Joseph M. Williams. 1995. The Craft of Research. Chicago, IL: The University of Chicago Press. This superb book presents a framework for dissecting arguments that can be applied in most situations.

3. Ueland, Brenda. 2007. If You Want to Write: A Book About Art, Independence, and Spirit. St. Paul, Minnesota: Graywolf Press. There is no better guide to sparking your creative process.

4. Hughes, William. 1997. Critical Thinking: An Introduction to the Basic Skills. 2d Peterborough, Ontario: Broadview Press. This clearly written and accessible book is a marvelous introduction to logical argument.

5. U.S. Bureau of the Census. 2008. The Statistical Abstract of the United States 2008. 127th edition Washington D.C.: U.S. Government Printing Office <http://www.census.gov/compendia/statab>. One of the most important data sources for any U.S. researcher. The plot's a bit thin, but the content's superb.

6. Norman, Donald A. 1990. The Design of Everyday Things. New York, NY: Doubleday/Currency. This fascinating book explores how humans interact with technology, and gives guidance to designers on how to make their products a joy to use.

7. Schwartz, Peter. 1996. The Art of the Long View: Planning for the Future in an Uncertain World. New York, NY: Doubleday. Lively and realistic scenarios are crucial tools for decision makers, and Schwartz describes how to create them in this classic book.

8. Heath, Chip, and Dan Heath. 2007. Made to Stick: Why Some Ideas Survive and Others Die. New York, NY: Random House. This book contains insightful and practical guidance for compelling story telling.

9. Tufte, Edward R. Envisioning Information. (1990). Visual Explanations: Images and Quantities, Evidence and Narrative. (1997). The Visual Display of Quantitative Information, 2nd ed. (2001). Cheshire, CT: Graphics Press. OK, I'm cheating a bit by calling these one book, but they are so good you'll want them all <http://www.edwardtufte.com>.

10. Few, Stephen. 2004. Show Me the Numbers: Designing Tables and Graphs to Enlighten. Oakland, CA: Analytics Press. This book complements Tufte's work, but is more business focused and practical.

11. Ringer, Robert J. 1974. Winning Through Intimidation. New York: Funk & Wagnalls. (Republished in 2004 as "To Be or not to Be Intimidated? That is the Question".) This book's philosophical and practical advice (and its humor) makes it one of my all-time favorites.